Key points from Lecture 25 of ASTR 350

1. Quantum mechanics is weird. But it works. Really, really well, in fact, which is why we accept that it is an excellent description of nature as revealed by our experiments and observations so far. But don't be misled by people who want to somehow import quantum philosophy into everyday activities; it's a scam.
2. A key concept of quantum mechanics is that things (e.g., photons or electrons) are described by *wave functions*, which describe the probability that a measurement would localize the thing in a given place. Indeed, one can consider objects as particles or waves. But the wavelike nature of everyday items is irrelevant because the associated wavelength is incredibly tiny and thus doesn't affect anything we see in our normal lives.
3. One consequence is the *uncertainty principle*. You can't know the position and momentum of anything, simultaneously, with perfect precision. In fact the product of the uncertainty Δx of the position with the uncertainty Δp of the momentum is always $\Delta x \Delta p \geq \hbar/2$, where $\hbar = h/(2\pi) = 1.055 \times 10^{-34}$ J s.
4. A lesser-known version of the uncertainty principle relates uncertainty in energy with uncertainty in time: $\Delta E \Delta t \geq \hbar/2$. This has the remarkable consequence that the energy isn't precisely known and so energy can be "borrowed" for a short time. Thus the vacuum, which we normally consider to be empty, is actually seething with "virtual pairs", which are particle-antiparticle pairs that pop into and out of existence in short intervals. The effect of these pairs is clear in atomic experiments; for example, precisely measured atomic energy levels show their effect.
5. If a particle-antiparticle pair appears near the horizon of a black hole, then sometimes the tidal gravitational field of the black hole can separate the two and make them real. The energy needed to do that is the combined energy of the two particles (these are usually photons), so if one falls in but the other escapes, the black hole radiates! This is Hawking radiation.
6. This takes a staggeringly long time; a solar-mass black hole in perfect vacuum would take $\sim 10^{67}$ years to evaporate. The evaporation time scales as M^3 for a black hole of mass M, so if there are very low-mass black holes from the early universe, some could have evaporated completely.
7. In addition to Hawking radiation being intrinsically cool, the process brings up many fundamental physics issues. However, we need to keep in mind that Hawking radiation from black holes has never been observed and, because it is so slow, might never be observed. So we shouldn't lose too much sleep about the implications, because *empirical* tests are not (yet?) possible.